BIOLOGICAL CONTROL OF THE CARIBBEAN FRUIT FLY (DIPTERA: TEPHRITIDAE)

RICHARD BARANOWSKI[1], HOLLY GLENN[1], AND JOHN SIVINSKI[2]
[1]University of Florida
Tropical Research and Education Center
Institute of Food and Agricultural Science
University of Florida
Homestead, FL 33031

[2]Insect Attractants, Behavior, and Basic Biology Research Laboratory,
Agricultural Research Service
U.S. Department of Agriculture,
Gainesville, Florida 32604

ABSTRACT

Parasitic Hymenoptera were introduced into Florida in an attempt to bring the Caribbean fruit fly (caribfly) under biological control. A total of 15 species of parasites from 4 families were imported. Twelve species were released, 9 have been recovered in the field, and 5 are considered established. These coexist with both endemic fruit fly parasites and generalist species, which serendipitously attack caribfly. Inundative releases of the braconid *Diachasmimorpha longicaudata* (Ashmead) to control caribfly are presently being tested by USDA/ARS, the University of Florida, and the Florida Division of Plant Industry. It is hypothesized that releases of parasites will augment numbers of natural enemies during periods when wasps are relatively uncommon due to difficulties in host finding. The lower numbers of flies that may result could be important in creating and maintaining fly-free zones. A renewed interest in the biological control of fruit flies promises future explorations for new natural enemies and novel means of employing them.

RESUMEN

Especies de hymenopteros parasiticos fueron introducidos en Florida con el fín de mantener la mosca del Caribe bajo control biológico. Se importaron un total de 15 especies de parásitos los cuales pertenecian a 4 familias. Estos coexisten con los parásitos endémicos y especies generalistas, las cuales atacan la mosca del Caribe. Liberaciones masivas de el braconido *Diachasmimorpha longicaudata* (Ashmead) estan siendo realizadas por el USDA/ARS, la Universidad de Florida y la Florida Division of Plant Industry. La hipotesis es que las liberaciones de parasitos aumentarán los números de enemigos naturales durante periodos en que las avispas son poco comunes dada la cantidad menor de hospederos. Las pocas moscas que se encuentren pueden ser importantes en el mantenimiento de zonas libres de moscas. El interés renovado del control de la mosca de la fruta promete que se realizarán mas exploraciones de enemigos naturales y nuevos metodos seran también utilizados.

The Caribbean fruit fly (caribfly), *Anastrepha suspensa* (Loew), has been introduced and established in Florida on at least two occasions. It was first reported from Florida based on adults collected at Key West in 1931. In early 1932, a quarantine was set up to prohibit the removal of host fruits from Key West and adjacent islands, and in 1933 an eradication campaign was initiated by the Florida Department of Agriculture, Division of Plant Industry (formerly the State Plant Board). This campaign ended in 1936 when it was decided that eradication was not practical because *A. suspensa* had also been found on the upper Keys and on the mainland. Apparently the population could not sustain itself as no additional specimens were collected between 1936 and 1959 when two adults were trapped at Key West. No further finds were noted until April 23, 1965, when larvae were found in Surinam cherries (*Eugenia uniflora* L.) in Miami Springs. Four days later, adults were trapped in the same area, and by the end of June, thousands had been trapped. Since 1965, *A. suspensa* has spread into 30 counties throughout the southern and central portions of Florida, extending as far north on the east coast as St. Johns County and on the west to Hernando County. More than 90 kinds of fruit have been recorded as hosts, those preferred being guava (*Psidium guajava* L.), peach (*Prunus persicae* Batsch), Surnam cherry, tropical almond (*Terminalia catappa* L.), and loquat (*Eriobotrya japonica* Lindl). Other fruits that are attacked include mango (*Mangifera indica* L.) and grapefruit (*Citrus X paradisi*) as well as other kinds of citrus (Norrbom 1988).

Early investigations showed that several species of hymenopterous parasitoids were already using the caribfly as a host, although the number parasitized was low. Those already present were *Spalangia cameroni* Perk., *S. endius* Walker, *Pachycrepoideus vindemiae* (Rond) (Pteromalidae), a *Cothonaspis* species (Eucoilidae), and a *Trichopria* species (Diapriidae). These parasitoids are not specific and attack other kinds of flies such as house flies. In addition, two braconid parasitoids *Bracanastrepha (=Opius) anastrephae* (Vier.) and *Doryctobracon anastrephilum* (Marsh) were recovered. Both of these parasitoids are specific to fruit fly larvae and undoubtedly existed in Florida as parasitoids of another species of fruit fly *Anastrepha interrupta* Stone which is only known to attack the fruit of an uncommon native plant *Schoepfia chrysophylloides* (A. Rich.).

Since fewer than 1% of Caribbean fruit fly pupae that were collected were parasitized, it was decided to introduce additional species of parasitoids in an attempt to reduce Caribbean Fruit fly populations (see Table 1). Introductions began late in 1967 with the cooperation of several scientists and agencies: Dr. F. D. Bennett, Commonwealth Institute of Biological Control, Trinidad; Drs. L. Steiner, T. T. Wong, D. L. Chambers, USDA Pacific Basin Area Tropical Fruit and Vegetable Research Laboratory, Hawaii; Mr. Robert Rhode, Organismo International Regional de Sanidad Agropecuaria (OIRSA), Costa Rica; Ings. D. L. Arrieta, Elezer Jimenez Jimenez, Direccion General de Sanidad Vegetal, Mexico, and Dr. R. Pralavorio (INRA), Antibes, France.

The first parasitoid released was *Doryctobracon areolatus* (Szepligeti) obtained from the Commonwealth Institute of Biological Control, Trinidad. The original stock consisted of 7 males and 17 females. It was carried through six to seven generations in the laboratory and in July, 1969, 45 males and 26 females were released. From fruit samples taken one week after the initial release, 578 *A. suspensa* pupae were recovered, 22 of which were parasitized by *D. aureolatus* showing that the laboratory reared wasps were successful in seeking out infested fruit. Recoveries were made through September, 1969, with levels of parasitization ranging from 3.4% to 43%, averaging 13%. Parasitization rates during July and August of the following year averaged 49%. *D. aureolatus* populations have declined in the southern portion of the caribflies' range, apparently because of competition with other parasites. It remains abundant to the north in the Lake Okeechobee area (Sivinski, Calkins, Baranowski, unpublished data).

TABLE 1. PARASITOID INTRODUCTIONS INTO FLORIDA TO CONTROL THE CARIBBEAN FRUIT FLY.

Parasitoid	Stage Attacked[a]	Family	Source	Successfully Lab Reared	Total No. Released	Recovered	Established
Aceratoneauromyia indicum Silvestri	*L*	Eulophidae	Costa Rica ICA Colombia Texas A&M	Yes	4,100	Yes	Yes
Biosteres persulcatus Silvestri	*L*	Braconidae	USDA Hawaii	No	0	No	No
Biosteres arisanus (Sonan)	*E*	Braconidae	USDA Hawaii	Yes	9,204	No	No
Biosteres vandenboschi (Fullaway)	*L*	Braconidae	USDA Hawaii	Yes	2,258	Yes	?
Diachasmimorpha longicaudata (Ashmead)	*L*	Braconidae	USDA Hawaii	Yes	1,174,400	Yes	Yes
Diachasmimorpha tryoni (Cameron)	*L*	Braconidae	USDA Hawaii	Yes	30,622	Yes	?
Dirhinus giffardii Silvestri	*P*	Chalcidae	INRA France	Yes	89,538	No	No
Doryctobracon areolatus (Szepligeti)	*L*	Braconidae	CIBC Trinidad	Yes	974	Yes	Yes
Doryctobracon Crawfordi- (Viereck)	*L*	Braconidae	INIAP Ecuador	No	0	No	No
Doryctobracon trinidadensis (Gahan)	*L*	Braconidae	CIBC Trinidad	Yes	3,679	Yes	?
Opius bellus Gahan	*L*	Braconidae	CIBC Trinidad USDA Hawaii	No	0	No	No
Psyttalia concolor (Silvestri)	*L*	Braconidae	INRA France	Yes	32,938	Yes	Yes
Psyttalia fletcheri (Silvestri)	*L*	Braconidae	USDA Hawaii	No	1,755	No	No
Psyttalia incisi (Silvestri)	*L*	Braconidae	USDA Hawaii	No	2,834	Yes	?
Trybliographa daci Weld	*L*	Eucoilidae	INRA France	Yes	43,110	Yes	Yes

[a]Under stage attacked, refers to larval *L*, egg *E*, and pupal *P*.

Diachasmimorpha (=*Biosteres*) *longicaudatus* (Ash.), obtained from Mexico and Hawaii, was established in the laboratory in 1972. Laboratory studies indicated that this species was more successful than *D. aureolatus* in searching for and parasitizing larvae of *A. suspensa*. It was released at the Tropical Research and Education Center during November, 1972, and monitoring of fruit samples after the release indicated that it was established. Because this species easily became established with the release of only 20 to 30 individuals at a site, it was decided to disseminate it as widely as possible within the caribfly range. A novel approach was used. With the cooperation of the IFAS Extension Service, newspaper, radio and TV coverage, and support from Chapters of the Rare Fruit Council, Inc., "brown bags" of parasitoids were distributed to homeowners having infested fruit in their yards. Within the distribution period, several thousand homeowners picked up parasites to release in their yards. In the five year period after these releases in 21 counties, annual adult caribfly catches averaged about 40% lower than during the years before the parasitoid releases (trapping records of the USDA/ Plant Protection & Quarantine, and the Florida Department of Agriculture and Consumer Services, Division of Plant Industry).

In addition to *D. aureolatus* and *B. longicaudatus*, several other parasitoids have been studied in the laboratory, and some released. *Biosteres arisanus* (Sonan) (=*Biosteres oophilus*) is a parasitoid that attacks the egg of certain fruit fly species in Hawaii. Several thousand individuals were released in cooperation with Dr. P. Greany, USDA Insect Attractants, and Basic Biology Research Laboratory, Gainesville, Florida, during 1974 and 1975, but *B. arisanus* did not become established. *Opius bellus*, a larval parasitoid of *Anastrepha* species was introduced in small numbers from Trinidad, but it was not colonized in the laboratory and was not field released. *Dirhinus giffardii* Silvestri, a pupal parasitoid, *Psyttalia concolor* (Silvestri) and *Trybliographa daci* Weld, larval parasitoids, were obtained from the Institut National de la Recherche Agronomique (INRA) laboratory in France during 1977-1979. Each species was colonized in the laboratory using *A. suspensa* as a host, and 30-90 thousand of each were released in the field during the same period. Both *T. daci* and *P. concolor* have been recovered in small numbers, which indicates that they are established, but at very low numbers. *D. giffardii* has not been recovered in the field.

More recently, we have introduced *Doryctobracon trinidadensis* (Gahan), a large species from Trinidad that also attacks *Anastrepha* larvae. It has been successfully colonized in the laboratory and small-scale field releases were made during the summer and fall of 1985. Limited recoveries were made after releases, but it is not considered established.

Biosteres (=*Opius*) *vandenboschi* (Fullaway), *Psytallia incisi* (Silvestri) and *Diachasmimorpha tryoni* (Cameron), all larval parasitoids, also have been recently introduced from Hawaii. *B. vandenboschi* and *D. tryoni* were successfully colonized in the laboratory on caribfly larvae. All three were released in limited numbers, and all have been recovered in small numbers.

Even with the establishment of this battery of "biological weapons", the caribfly remains abundant and a serious pest. In fact, the classical biological control of any fruit fly to levels below economic threshold is often considered difficult or unfeasible (Debussy 1989, Wharton 1989). There are several generalizations that perpetuate this impression. (1) Most tephritids of economic importance can be found, at least periodically, in relatively large fruit. Fly larvae may safely live inside these larger fruits where their parasites' ovipositors cannot reach. For example, parasitism of the apple maggot, *Rhagoletis pomonella* (Walsh), by the opiine braconid *Biosteres melleus* (Gahan) is greater in hawthorn (*Crataegus sp.*) than in apple, presumably because of the latter's greater size (Porter 1928). In a similar instance, larvae of the olive fly, *Dacus oleae*, are sheltered in large host fruit from attack by *Psyttalis (-Opius) concolor* (Manikas &

Tsiroyannis 1982). However, in a year-long survey of 6 fruit species, a fruit's size was only weakly correlated to caribfly parasitism by *Diachasmimorpha longicaudata* (Sivinski 1991). This may be due to the parasite's extensive foraging over fallen fruit, which could allow it to attack larvae as they leave even the largest fruit to pupate, and a propensity for mature larvae to feed relatively close to the surface of many fruits. (2) Host discrimination (avoidance by foraging females of fruit previously marked by ovipositing parasites, Lawrence et al. 1978) may restrict the number of parasites produced per fruit. There is little evidence as yet that host discrimination by *D. longicaudata* plays an important role in restricting fly mortality in the field (JS & RB unpub. data). This may be due to the weaker response of female *D. longicaudata* to host-marking pheromones deposited after oviposition when parasites are at high density levels (Lawrence et al. 1978, JS & RB unpub. data). As host markers age, the reaction of parasites to them changes. After 5 days in the laboratory, such markers actually become attractive (JS & RB unpub. data). (3) There are pronounced time lags between the growth of host and parasite populations. For example, peak parasitism of the Mediterranean fruit fly (*Ceratitis capitata* (Wied.)) occurs after the fly has reached high levels (Wong et al. 1984). Regular seasonal fluctuations in fruit give fruit flies frequent opportunities to escape their natural enemies. (4) Fruit flies have greater fecundity and dispersal abilities than their parasites, so that even high parasitism levels (>90%) of a first generation of flies are insufficient to prevent the growth of a host population (Debussy 1989). (5) Finally, the economic threshold for control is very high for cultural and quarantine reasons. Fruit in the United States is often considered spoiled if a single maggot is present. The substantial reduction of caribfly larvae in guava from a mean of 50 to a mean of 5 is still of little commercial interest, although such a degree of control might be of practical importance in areas where fruit is grown for local consumption and is traditionally eaten flies and all, as in guava paste.

These arguments should not discourage biological control programs. There are certain conditions under which fruit fly natural enemies have been useful to American agriculture (Baranowski 1987; Bess & Haramoto 1958; T. Wong et al. 1991). A particularly favorable set of circumstances may presently exist for biological attack on the caribfly. The first positive factor is the low infestation rates in grapefruit, the host of principle economic importance in Florida. The second is the increasing application of the "fly-free zone" concept, where an absence of trapped flies captured during certain periods allows a grapefruit grower to export his crop without postharvest treatment on the presumption that the fruit are not infested. It has been suggested that fly-free zones could be created and maintained by simple suppression of fly numbers with parasites. This could be accomplished by increasing fly mortality in preferred hosts such as Surinam cherry, loquat, guava and tropical almond, which in turn might reduce the migration of flies into adjacent citrus. Lower migration, in theory, could result from there being both fewer flies to disperse as well as less motivation for the remaining flies to leave preferred hosts when competition for ovipositional sites is low. It was noted, for instance, that the host range of the Oriental fruit fly, *Bactrocera (Dacus) dorsalis*, shrank after the introduction of parasites into Hawaii (Bess & Haramoto 1958).

A major biological barrier to suppression, the lag between fly and parasite population growth, could be overcome by the establishment of new parasites that forage more effectively at low host densities or by inundative release of presently established parasites while fly numbers are at cyclical low points. Inundative releases of *D. longicaudata* and combinations of sterile male flies and parasites are presently being cooperatively tested by the USDA/ARS, University of Florida and Florida Division of Plant Industry. It should be noted that parasite mass releases have 2 potential advantages over sterile male releases. First, the parasites do not scar fruit as might happen when female flies are released along with sterile males. Second, there is no potential for the error, confusion, and delay that growers in fly-free areas might face when their traps capture flies which then must be examined and determined to be part of a sterile release.

Should inundatively released parasites prove to be a useful control for the caribfly, another barrier to their use still exists, the expense of production. This may be mitigated by the ability to separate laboratory-reared male and female fruit fly larvae by their different development rates. Female caribfly larvae develop more quickly than males and can be segregated when they leave the rearing medium to pupate (Sivinski & Calkins 1990). A perennial problem in fruit fly rearing facilities that provide insects for sterile releases is large numbers of unwanted females. These females are not thought to contribute significantly to the sterile control but do consume half the resources of the rearing program. If female caribfly larvae could be set aside as parasite hosts, what had been an expensive liability to a control program, could become an asset.

Most of the parasites released in Florida were originally obtained during explorations of the old world tropics soon after the second world war. The search at the time was for natural enemies of *Bactrocera* species. These parasites proved to have a broad host range that included *Anastrepha* spp. There is a growing interest within the USDA/ARS and universities for initiating a new generation of explorations, this time in Latin America. It is hoped that new parasites with specialized abilities may be found preying upon the 185 species of *Anastrepha* living in the American tropics. Parasites that attack the shallowly placed eggs of the caribfly or that have unusually long ovipositors, or that forage effectively at low host densities, would all be welcome candidates for classical or augmented releases.

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EFFICACY OF STERILE RELEASES OF CARIBBEAN FRUIT FLIES (DIPTERA: TEPHRITIDAE) AGAINST WILD POPULATIONS IN URBAN HOSTS ADJACENT TO COMMERCIAL CITRUS

T. C. HOLLER[1] AND D. L. HARRIS[2]
[1]USDA, APHIS, Science & Technology
Caribbean Fruit Fly Station
P.O. Box 147100
Gainesville, FL 32614-7100

[2]Florida Department of Agriculture & Consumer Services
Division of Plant Industry
P.O. Box 147100
Gainesville, FL 32614-7100

ABSTRACT

The sterile male release technique was tested either as an alternative to fumigation or as a supplement to a fly-free management program in 1988 for control of the Caribbean fruit fly, *Anastrepha suspensa* (Loew). The test area consisted of 19-28 sq. kilometers with a corresponding non-sterile fly release area. Releases began in January, 1988, and continued generally through June 1990. Efficacy was measured by determining the presence or absence of flies using an aggressive trapping program. Suppression of wild *A. suspensa* in the first year could not be measured easily but, by the end of the third year, measurable reduction was evident.

RESUMEN

La tecnica de machos esteriles fue probada como una alternativa a la fumigación o como un suplemento a el programa de manejo de zonas libres de moscas para el control de la mosca de la fruta del Caribe, *Anastrepha suspensa* (Loew). El area experimental consistió de 19-28 kilometros cuadrados. Las liberaciones comenzaron en Enero, 1988 y continuaron hasta Junio 1990. Se midió la eficacia de las liberaciones por medio de un trampeo intensivo. La supresión de *A. suspensa* no pudo ser medida facilmente durante el primer año, pero al final del tercer año, la reducción fue evidente.